

**MINI-FOCUS ISSUE: TAVI**  
**State-of-the-Art Paper**

# Transcatheter Aortic Valve Implantation for Failing Surgical Aortic Bioprosthetic Valve

## From Concept to Clinical Application and Evaluation (Part 1)

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With an aging population, improvement in life expectancy, and significant increase in the use of bioprosthetic valves, structural valve deterioration will become more and more prevalent. The operative mortality for an elective redo aortic valve surgery is reported to range from 2% to 7%, but this percentage can increase to more than 30% in high-risk and nonelective patients. Because transcatheter aortic valve (TAV)-in-surgical aortic valve (SAV) implantation represents a minimally invasive alternative to conventional redo surgery, it may prove to be safer and just as effective as redo surgery. Of course, prospective comparisons with a large number of patients and long-term follow-up are required to confirm these potential advantages. It is axiomatic that knowledge of the basic construction and dimensions, radiographic identification, and potential failure modes of SAV bioprostheses is fundamental in understanding key principles involved in TAV-in-SAV implantation. The goals of this paper are: 1) to review the classification, physical characteristics, and potential failure modes of surgical bioprosthetic aortic valves; and 2) to discuss patient selection and procedural *techniques relevant to TAV-in-SAV implantation*. (J Am Coll Cardiol Intv 2011;4: 721–32) © 2011 by the American College of Cardiology Foundation

During the last decade, the relative use of bioprosthetic aortic valves has increased by nearly 80% (1). Improvements in surgical techniques and valve durability are likely to have fueled this increase (2). Based on clinical and microsimulation studies, several investigators suggest that we should lower the age cutoff for bioprosthetic aortic valve replacement from 65 to 60 years (3–5).

The actuarial freedom from reoperation for a failing bioprosthetic valve is approximately 95%, 90%, and 70% at 5, 10, and 15 years, respectively (6–10).

In fact, the lifetime risk of reoperation decreases with increasing patient age at the time of implantation (Fig. 1) (11). More specifically, the lifetime incidence of reoperation can be as high as 25% and 45% in those patients with a primary operation at 50 and 60 years of age, respectively.

Over the last 2 decades, the mortality risk of redo aortic valve surgery has decreased appreciably. The operative mortality for an elective redo aortic valve surgery is reported to range from 2% to 7%, but this percentage can increase to more than 30% in high-risk and nonelective patients (12–22). Although redo surgery can be associated with low mortality in selected patients, it can lead to significant morbidity *including* blood transfusion requirements, wound infection, post-operative pain, and/or delayed recovery.

Transcatheter aortic valve implantation (TAVI) may represent an alternative treatment to conven-

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tional aortic valve replacement for high or prohibitive surgical risk patients (23–27). By virtue of its minimally invasive nature, TAVI avoids sternotomy and cardiopulmonary bypass and can potentially reduce resource utilization by accelerating patient recovery and reducing length of hospital stay.

In 2007, Wenaweser et al. (28) reported the first case of a transcatheter valve (Medtronic CoreValve system, Medtronic CV Luxembourg S.a.r.l., Luxembourg, Germany) implanted into a degenerated surgical aortic bioprosthesis. Since then, numerous case reports of transcatheter aortic valve-in-surgical aortic valve (TAV-in-SAV) implantation have been described (29–46).

It is axiomatic that knowledge of the basic construction and dimensions, radiographic identification, and potential failure modes of SAV bioprostheses is fundamental in understanding key principles involved in TAV-in-SAV implantation. The goals of this paper are: 1) to review the classification, physical characteristics, and potential failure modes of surgical bioprosthetic aortic valves; and 2) to discuss patient selection and procedural *techniques relevant to* TAV-in-SAV implantation.

## Abbreviation and Acronym

**SAV** = surgical aortic valve  
**TAVI** = transcatheter aortic valve implantation  
**TAV-in-SAV** = transcatheter aortic valve-in-surgical aortic valve

## Bioprosthetic SAV

**Types and construction.** SAV replacement with a bioprosthesis can be performed using either a stented or stentless valve (Table 1, Fig. 2). Valve leaflets can be of xenograft (specifically, porcine aortic valve or bovine pericar-

dium) or homograft origin.

**STENTED VALVES.** Stented valves are typically constructed using a base ring that is covered by a fabric sewing cuff and from which a stent or frame arises at a right angle to support the valve leaflets (Fig. 3). Depending on the model, the base ring is either circular- or scalloped-shaped and may consist of molded silicone rubber (with or without tungsten powder), cobalt-chromium-tungsten (Haynes alloy), stellite, or stainless steel. Modern day biological surgical valves are engineered using a flexible stent/frame that attempts to absorb, and thereby mitigate, the loading stress on the tissue leaflets during valve closure. The stent/frame can be made of cobalt-nickel alloy (Elgiloy), polypropylene, acetyl homopolymer (Delrin), acetyl copolymer (Celcon), or titanium and have metallic components. The base ring and stent/frame can be exteriorized by Dacron, pericardium, polytetrafluoroethylene, or some other polyester fabric; at the level of the base ring, this exteriorization forms the basis of the suture ring. It is evident by now that stented valves may or may not be radiopaque. Correct positioning and deployment of transcatheter valves during a TAV-in-SAV procedure requires correct radiographic recognition of stented bioprostheses.

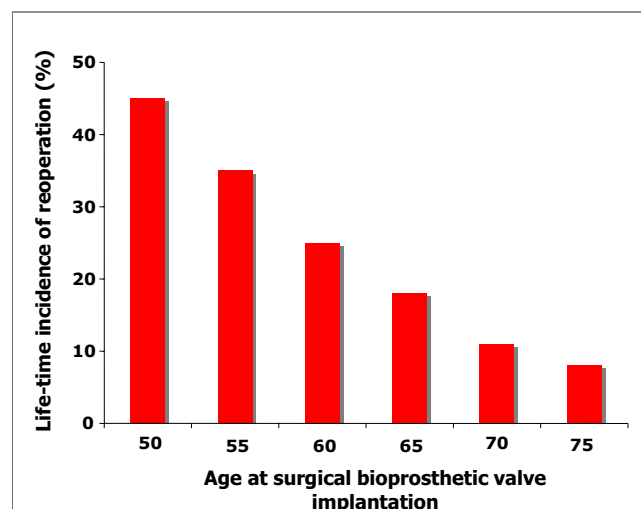
**Table 1. Classification of Stented and Stentless Bioprostheses on the Basis of Tissue Type**

Stented		
Bovine Pericardial	Porcine Aortic Valve	
Edwards Perimount	Medtronic Hancock I and II	
Sorin Mitroflow	Medtronic Modified Orifice	
Sorin Soprano	Medtronic Mosaic	
	Carpentier-Edwards Supra-Annular Valve	
	St. Jude Medical Biocor/Epic	
Stentless		
Bovine Pericardial	Porcine Aortic Valve	Homograft
Sorin Freedom	Medtronic Freestyle	CryoValve
ATS Medical	St. Jude Toronto SPV	Ross procedure
	St. Jude Biocor	
	Edwards Prima	
	CryoLife O'Brien	
Biocor, Epic, and Toronto are products of St. Jude Medical (Minneapolis, Minnesota). CryoValve and O'Brien are products of CryoLife (Kennesaw, Georgia). Freedom, Mitroflow, and Soprano are products of Sorin Group (Saluggia, Italy). Perimount, Prima, and Supra-Annular Valve are products of Edwards Lifesciences (Irvine, California). Freestyle, Hancock, Modified Orifice, and Mosaic are products of Medtronic (Minneapolis, Minnesota).		
SPV = stentless porcine valve.		

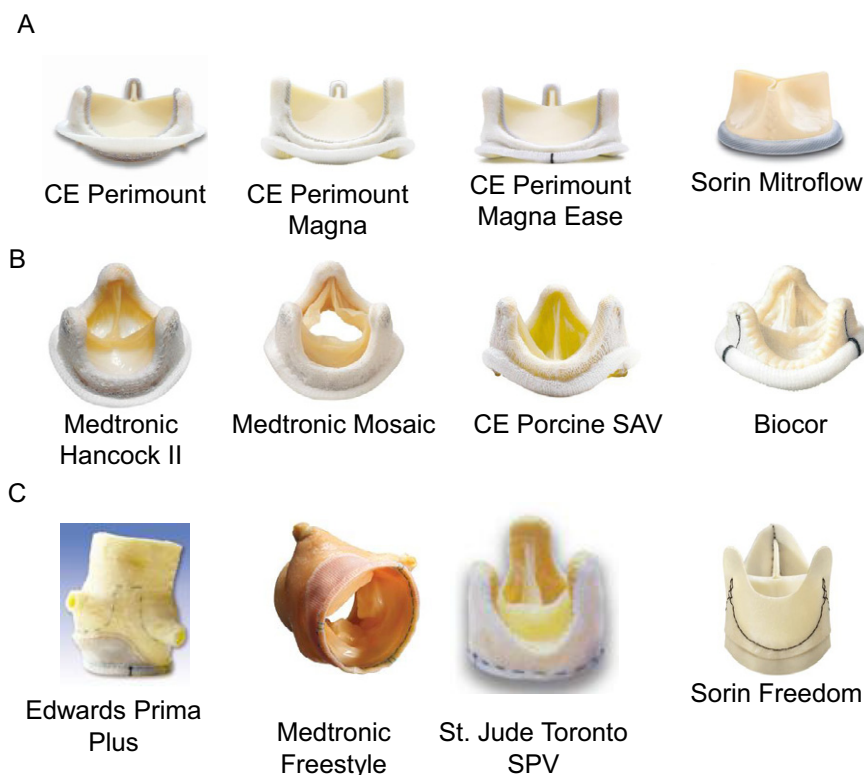
Biocor, Epic, and Toronto are products of St. Jude Medical (Minneapolis, Minnesota). CryoValve and O'Brien are products of CryoLife (Kennesaw, Georgia). Freedom, Mitroflow, and Soprano are products of Sorin Group (Saluggia, Italy). Perimount, Prima, and Supra-Annular Valve are products of Edwards Lifesciences (Irvine, California). Freestyle, Hancock, Modified Orifice, and Mosaic are products of Medtronic (Minneapolis, Minnesota).

SPV = stentless porcine valve.

Several dimensions characterize stented valves (Fig. 4). To better appreciate these dimensions, it is important to recall the various components of the bioprosthesis: the leaflets, the base ring and covering cloth (suture ring), and the stent/frame. Thus, leaflet thickness and the suture ring (base ring and cloth) profile can influence the potential space for blood flow. The inner base ring diameter (commonly referred to as the inner stent diameter) is measured from the inner surface to inner surface of the base ring. The outer base ring diameter (commonly referred to as



**Figure 1. Lifetime Risk of Reoperation as a Function of Age at Surgical Aortic Valve Replacement**



**Figure 2. Types of Stented and Stentless Valves**

(A) Stented pericardial bovine bioprosthetic valves. (B) Stented porcine aortic valve bioprostheses. (C) Stentless bioprosthetic valves. These lists are nonexhaustive. CE = Carpentier-Edwards; SPV = stentless porcine valve.

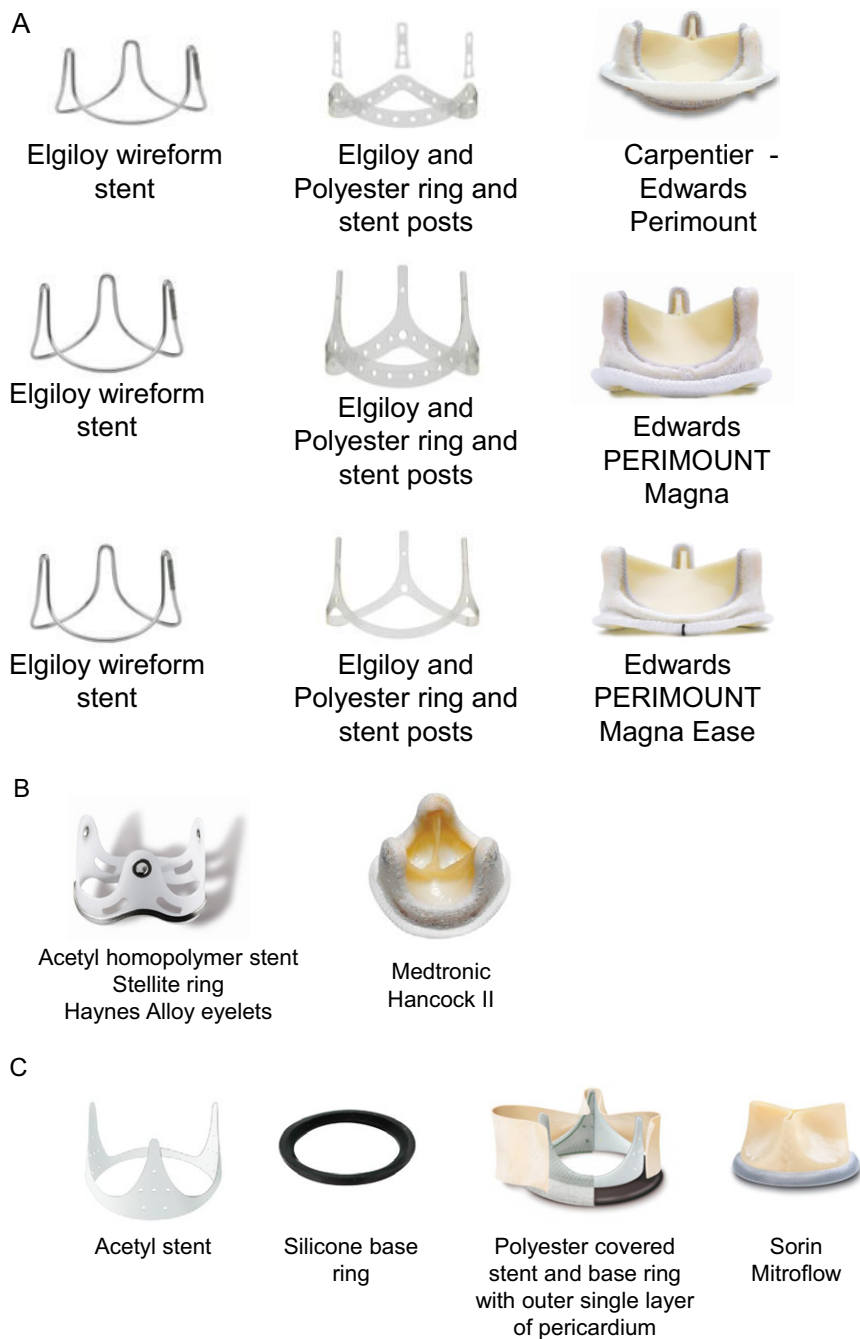
the outer stent diameter) is measured from the outer surface to outer surface of the base ring and thereby excludes the thickness of the covering cloth. The outer suture ring diameter (also known as the external diameter) is measured from the outer undisturbed sewing cuff surface to outer cuff surface.

Selection of prosthetic valve size is typically performed intraoperatively using manufacturer-specific sizing tools and can be influenced by factors such as operator experience, philosophy or bias, and extent of leaflet resection and annular decalcification. Whereas the inner base ring diameter is an important factor influencing post-operative gradients, the outer suture ring diameter typically determines the maximal valve size that can be inserted. By reducing the thickness of the base ring or profile of the sewing cuff, manufacturers can maximize the inner base ring diameter for a given annulus size.

In addition to the diameter of the outer suture ring, the position in which the prosthesis is inserted relative to the annulus (i.e., intra- or supra-annular) can also influence maximal valve selection. Whereas the first-generation Hancock (Medtronic Inc., Minneapolis, Minnesota) and Carpentier-Edwards (Edwards Lifesciences, Irvine, California) valves were designed for intra-annular insertion, second- and third-generation

valves such as the Medtronic Mosaic, Carpentier-Edwards Magna (Edwards Lifesciences), and Sorin Soprano (Sorin Group, Milan, Italy) are designed to be implanted supra-annularly. Supra-annular positioning allows the aortic sinuses to accommodate the bulk of the cuff tissue and thereby liberate the left ventricular outflow tract from obstructive material. What follows then, is that a supra-annular prosthesis allows for a larger inner stent diameter in a given patient.

Of particular note, the manufacturer's labeled valve size (in millimeters) does not match the inner base ring diameter or any significant hemodynamic-related dimension of the valve (47–49). The labeled valve size of most manufacturers, however, corresponds to the outer base ring diameter. In reality, there is no homogeneity across manufacturers when it comes to labeling valve size. This fact becomes important when comparing the clinical and hemodynamic outcomes of “similar” labeled valve sizes from different valve manufacturers. Despite the call for standardization of “valve size labeling” from several surgical groups, discrepancies among manufacturers remain (47–49). Later on, we will discuss the importance of the inner base ring diameter as it relates to transcatheter valve size selection for TAV-in-SAV.



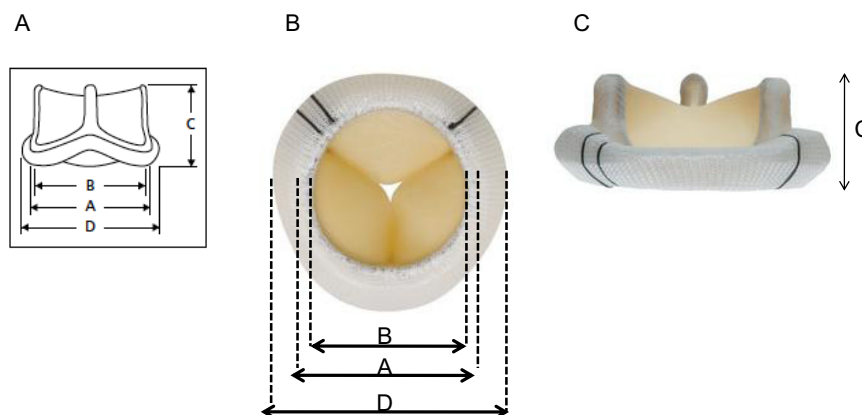
**Figure 3. Stented Bioprosthetic Valves Consist of a Base Ring and Stent With Supporting Posts**

(A) Carpentier-Edwards Perimount (Edwards Lifesciences, Irvine, California) bovine pericardial valves. (B) Medtronic Hancock II (Medtronic Inc., Minneapolis, Minnesota) porcine aortic valve bioprostheses. (C) Sorin Mitroflow (Sorin Group, Milan, Italy) bovine pericardial bioprosthesis.

Online Appendix 1 provides the dimensions of the outer suture ring diameter, outer base ring diameter, inner base ring diameter, and valve height for commonly inserted stented aortic valves.

**STENTLESS VALVES.** Stentless valves, as the name implies, do not have a stent/frame or base ring. As described in

Table 1, these valves may be of heterograft, autograft, or homograft origin. A thin strip of nonexpansible cloth (e.g., Dacron) may cover the inflow tract to provide extra support and facilitate the suturing of the prosthesis to the left ventricular outflow tract (Fig. 2).



**Figure 4. Dimensions of Stented Bioprosthetic Valves**

(A) Diagrammatic representation of stented bioprosthetic valve dimensions where A = outer stent diameter; B = inner stent diameter; C = prosthesis height; and D = outer sewing ring diameter. (B) Inferior (ventricular) view of stented bioprosthesis. (C) Side view of stented bioprosthesis.

With the lower profile and nonobstructive properties of stentless valves came the anticipated reduction in transvalvular gradients and improved flow characteristics with respect to stented valves (50,51). Furthermore, these valves were expected to perform better in small aortic roots (52). Notwithstanding the technical demands required for stentless procedures, there have been conflicting reports on their purported benefits (53,54).

With a few exceptions, the labeled size of a stentless valve corresponds to its outer diameter (in millimeters). With the absence of a rigid base ring, the relevant dimensions of a stentless valve include its inner and outer diameter. Online Appendix 2 provides the dimensions of the inner and outer diameters and height for commonly inserted stentless aortic valves.

### Radiographic/Fluoroscopic Identification of SAV Bioprostheses

Stented valves are identified by recognizing radiopaque components of the base ring and/or stent on fluoroscopy (Fig. 5) (55,56). Stentless valves, on the other hand, do not have any radiopaque components. With either valve type, calcifications may help with identifying the margins and location of the prosthesis.

Fluoroscopic analysis of the prosthesis should begin with identification of the base ring (Figs. 3 and 5). The base ring may or may not be radiopaque. Furthermore, the shape of the base ring (circular, boat-, or hammock-shaped) and whether the ring is open or closed will help distinguish between valve types.

The second step requires characterization of the stent/frame. Again, this component may or may not be radiopaque. The base ring can be a continuous structure with the stent; in these cases, analysis of the angle with

which the struts emerge from the base ring can be informative (Figs. 5E to 5G). In some cases, such as with the Medtronic Hancock II or Mosaic prosthesis, the stent struts are radiolucent except for tiny circular eyelets near their apices (Figs. 5B to 5D).

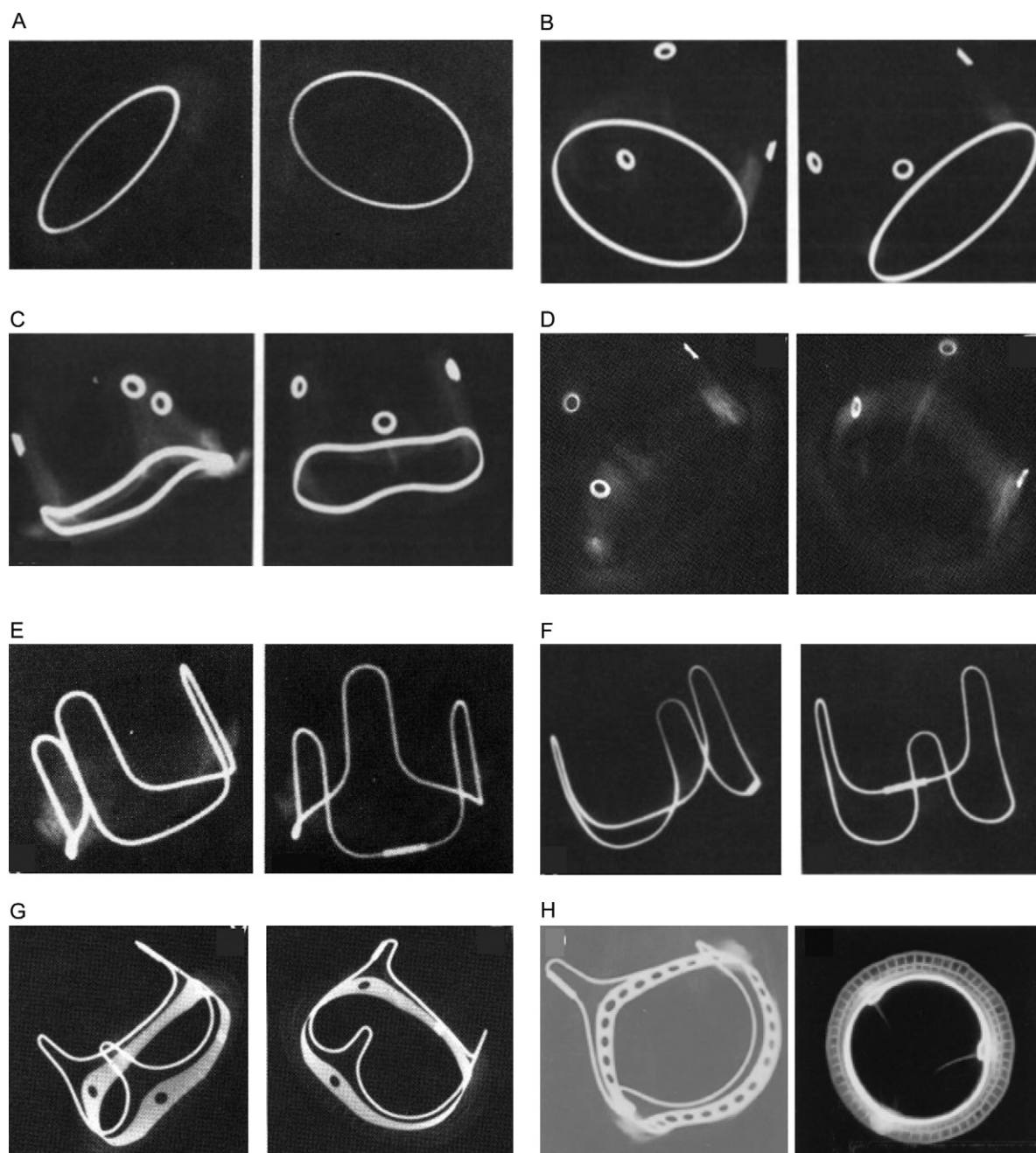
### Causes and Mechanisms of Bioprosthetic Valve Failure

Time-related structural valve dysfunction leading to regurgitation or stenosis is the major drawback of bioprosthetic valves. Fortunately, the vast majority of valve failures are nonfatal and progress slowly; if identified in a timely manner, an elective redo surgery can be performed with relative safety. Structural valve dysfunction is age-dependent. In fact, it is nearly uniform by 5 years in those <35 years of age, but occurs in only 10% in those >65 years of age within 10 years (Fig. 1).

It is beyond the scope of this manuscript to provide a detailed description of the explant pathology and modes of bioprosthetic valve failure (57–60). Failure modes can be influenced by: 1) host metabolic pathways; 2) bioprosthesis engineering and chemistry (e.g., leaflet suturing material, stent post flexibility, prosthesis fabric covering, leaflet fixation process); and 3) mechanical loading effects (e.g., leaflet flexural stress/strain). Broadly speaking, bioprosthetic valve failure can be the result of calcification, wear and tear, pannus formation, thrombosis, and/or endocarditis (Fig. 6).

Leaflet tissue deterioration, whether calcific or noncalcific, is the major cause of bioprosthetic valve failure (57–60). Although the glutaraldehyde fixation process of bioprosthetic heart valves is intended to promote tissue durability by creating stable cross links between collagen fibers and render the heterograft material biologically inert, residual glutaraldehyde-derived polymers may serve as

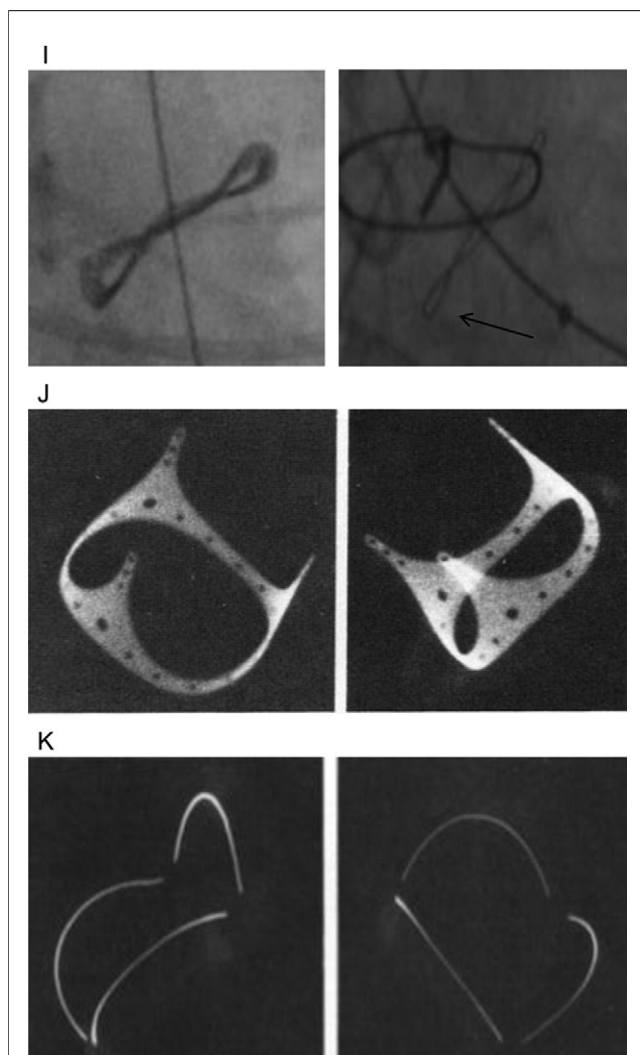




**Figure 5. Radiographic Appearances of Various Stented Bioprosthetic Valves**

(A) The Hancock standard valve has a radiopaque Haynes alloy flat base ring. (B) The Hancock Modified Orifice valve has a radiopaque flat base ring (Haynes alloy) and metal eyelets (Haynes alloy) located at the apices of each stent post. (C) The Medtronic Hancock II valve has a radiopaque saddle-shaped base ring (Haynes alloy) and metal eyelets (Haynes alloy) located at the apices of each stent post. (D) The Medtronic Mosaic valve has radiopaque metal eyelets only. (E) The Carpentier-Edwards (CE) Porcine Standard valve has a radiopaque continuous wire form (Elgiloy) that outlines the stent posts (U-shaped loops) and the base ring between the stent posts. The base ring is otherwise radiolucent. (F) The CE Porcine Supra-Annular Valve (SAV) is similar to the CE Porcine Standard valve (E) except that the CE porcine SAV has "less sharp" transition angles between base ring and stent posts. (G) The CE Pericardial valve has a flattened radiopaque base ring with 3 holes. A narrow wire form (Elgiloy) outlines the 3 stent posts and the base ring in between. (H) The CE Perimount standard has a radiopaque base ring that contains multiple holes and a separate narrow wire form (Elgiloy) that outlines the stent posts and the base ring in between. As shown in Figure 3, the base ring of the CE Perimount can differ depending on the model (e.g., Magna, Magna Ease). Furthermore, the metal stent posts of the CE pericardial valves form a very tight "U," whereas the CE porcine valves have a more open "U."

*Continued on next page.*



**Figure 5. Continued**

(I) The Sorin Mitroflow valve (left) and Sorin Soprano valve (right) have a radiopaque saddle-shaped base ring. The stent posts are not visible. In contrast to the Sorin Mitroflow, the Soprano valve has a narrower base ring profile. (J) The Ionescu-Shiley Standard valve has a radiopaque base ring with multiple holes that is continuous with the stent posts that are characterized by 3 holes. (K) The Ionescu-Shiley low profile valve has 3 narrow wire form arcs separated by radiolucent areas highlighting the base ring. Figures 5A, 5E, and 5K are reprinted, with permission, from Mehlmán et al. (56). Figures 5D, 5F, 5G, and 5K are reprinted, with permission, from Mehlmán (55). Figures 5B and 5C are reprinted, with permission, from Mehlmán DJ. A pictorial and radiographic guide for identification of prosthetic heart valve devices. *Prog Cardiovasc Dis* 1988;30:441–64.

calcium-binding sites that promote calcium-phosphate precipitates. Furthermore, toxic glutaraldehyde may result in cell death of bioprosthetic valve leaflets and host fibroblasts/macrophages. The mitochondria of dead cells, rich in phosphate, can be an additional source of calcium-binding sites. For these reasons, anticalcification treatments (e.g., Edwards ThermaFix, Medtronic AOA) serve to reduce

potential binding sites by: 1) residual glutaraldehyde subtraction; 2) phospholipid extraction; and/or 3) terminal liquid sterilization.

Calcific deposits have a propensity to develop in areas where leaflet flexion and stress are greatest; that is, at the basal and commissural attachment points. Approximately three-fourths of patients with leaflet calcification and tears suffer from aortic regurgitation (57–60). Because significant aortic regurgitation can be associated with large stroke volumes, transcatheter prostheses can be difficult to position accurately unless rapid pacing is performed during deployment.

Pannus represents a host tissue response and develops at the host-prosthesis interface. Early pannus is composed of myofibroblasts, fibroblasts, and capillary endothelial cells. Overtime pannus may calcify. Some pannus formation over the suture is normally expected and functions to form a nonthrombogenic surface. When exuberant, however, it may extend to the leaflets and contribute to leaflet stiffening and dysfunction. Pannus formation is usually mild and can be detected in the vast majority (~70%) of explanted valves.

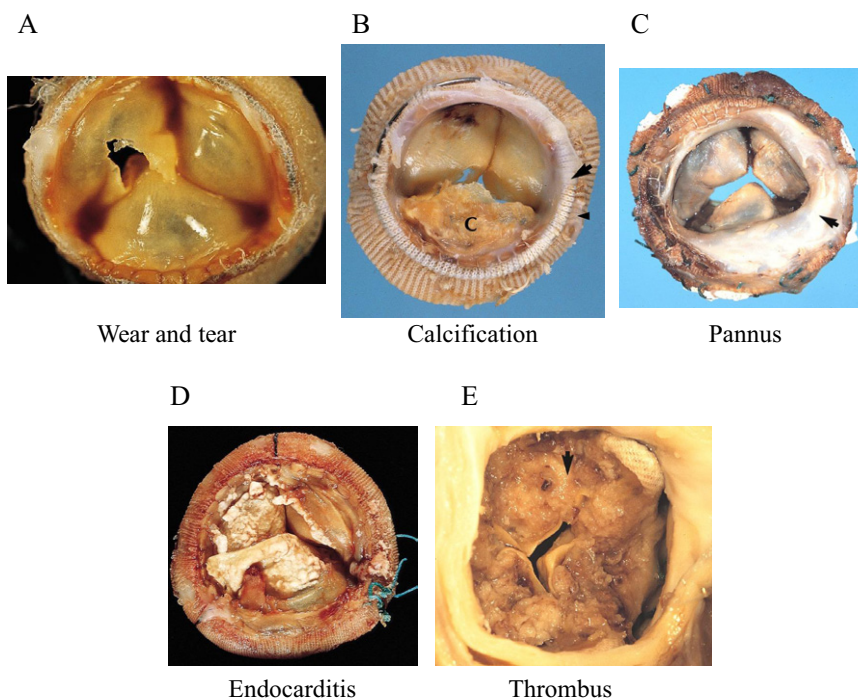
Thrombosis and endocarditis occur less frequently than the aforementioned modes of bioprosthetic failure, occurring at a rate of 0.2% per year and 1.2% per year, respectively (61).

In elective, low-risk patients, redo surgery can be performed with a low mortality risk, which is comparable to the primary valve operation (13–15,19,20). Still, there are patients for whom a second operation carries an unacceptable risk for the physician and/or patient. Furthermore, redo surgery can be associated with significant morbidity such as blood transfusions, renal failure, wound infection, post-operative pain, and delayed recovery. For these patients, TAV-in-SAV can provide a lesser invasive approach potentially associated with lower morbidity and mortality than conventional surgery.

## Procedural Aspects of TAV-in-SAV Implantation

**Transcatheter valve size selection.** Technical details of the primary valve surgery will help confirm the type and size of bioprosthesis. Transcatheter valve size selection depends on a number of factors such as the manufacturer's internal stent diameter, information gleaned from multiple imaging modalities (specifically transesophageal echocardiography, transthoracic echocardiography, and multislice computed tomography), mode of failure, and hemodynamic expectations based on patient body size and risk profile.

As was previously stated, a discrepancy exists between the labeled valve size and the internal stent diameter of the prosthesis (47–49). A reference table, such as provided in Online Appendix 1, should be used to obtain the internal stent diameter of the prosthesis and guide transcatheter valve size selection. Severe calcification or excessive pannus growth, however, may cause a mismatch between the measured and manufacturer listed internal stent diameter.



**Figure 6. Pathological Specimens Showing the Most Common Reasons for Bioprosthetic Valve Failure**

(A) Wear and tear. (B) Calcific degeneration. (C) Pannus. (D) Endocarditis. (E) Thrombus. Wear and tear (A) and calcification (B) are the most common reasons for bioprosthetic valve failure.

When TAVs are implanted into native aortic valves, prostheses are typically oversized relative to the annulus diameter by 10% to 30%. Whether sizing principles should differ for a TAV-in-SAV implantation, and even more specifically, between nondistensible stented valves and “somewhat” distensible stentless valves is yet to be determined. In the absence of any firm evidence or recommendations, we continue to use the manufacturer’s sizing principles (23- and 26-mm Edwards Sapien valve for aortic annuli measuring 18 to 21 mm and 22 to 25 mm, respectively; 26- and 29-mm Medtronic CoreValve for aortic annuli measuring 20 to 23 mm and 24 to 27 mm, respectively). Inevitably, because of the restricted dimensions of the internal base ring, the majority of TAV-in-SAV procedures will be performed with the “smaller” sized transcatheter valve.

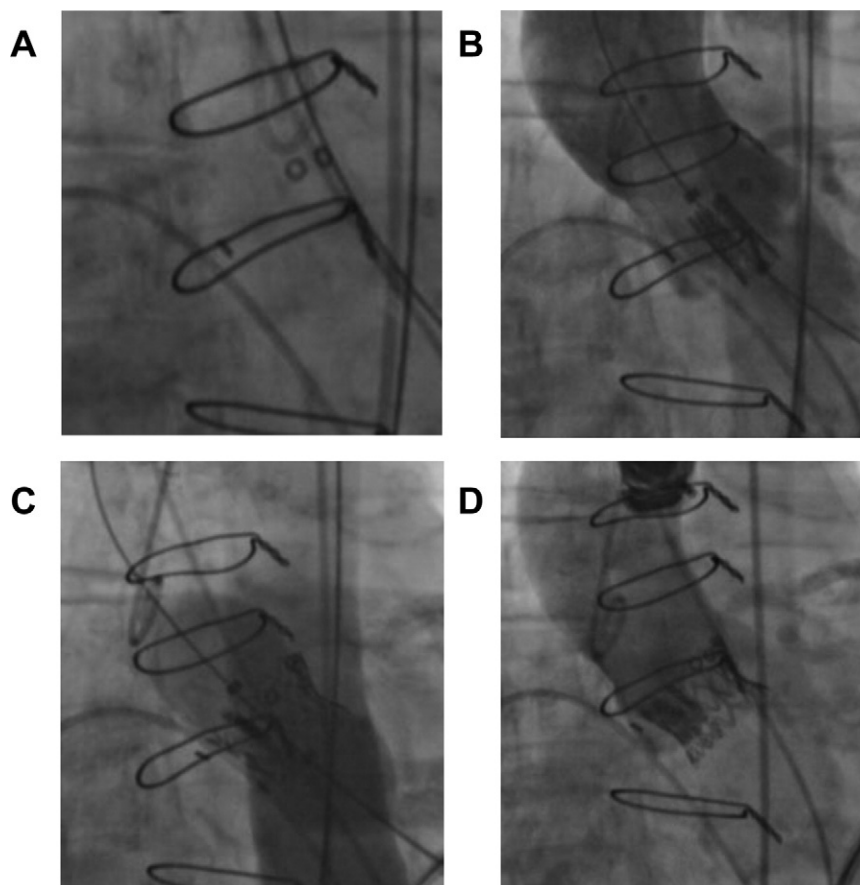
An undersized transcatheter valve may increase the risk of paravalvular leak or migration/embolization. On the other hand, oversizing may lead to geometrical distortion of the transcatheter valve leaflets and influence its durability.

Experimental work in this field is extremely limited. Using pulse duplicators, Azadani et al. (62) recently examined the hemodynamic behavior of a 23-mm TAV implanted within *degenerated* small-sized Carpentier-Edwards Perimount bioprostheses (19, 12, and 23 mm). The investigators noted that the rigid base ring and the stent posts of the bioprosthesis prevented full expansion of the transcath-

eter valve in all cases. Although the transvalvular gradients decreased significantly in the 23- and 21-mm bioprostheses, there was no improvement within the 19-mm Perimount bioprosthesis. Furthermore, there was significant central aortic regurgitation with the 19-mm Perimount bioprosthesis. The investigators concluded that the rigid base ring and stent posts appear to offer adequate anchorage for the TAV. With the currently available transcatheter aortic valves, a TAV-in-SAV implantation within a 19-mm surgical bioprosthesis may yield unacceptable hemodynamics and should be discouraged.

**Pre-implant balloon aortic valvuloplasty.** As will be appreciated in the summary of published case reports, practice patterns across hospitals are heterogeneous. The benefits and/or risks associated with pre-implant balloon dilation are currently unknown. During routine TAVI, pre-implant balloon aortic valvuloplasty, through cracking of calcific deposits, is believed to improve the annular “seating space” and allow for maximal transcatheter valve expansion. This concept may apply for TAV-in-SAV when severe calcification is the mode of failure. In other situations, the value of dilating a “nondistensible” stented valve can be debated. Furthermore, there is concern that pre-implant balloon aortic valvuloplasty within degenerated bioprostheses may cause friable material to embolize. According to the American College of Cardiology/American Heart Association and Eu-





**Figure 7. Munich Case Example: Transapical 23-mm Edwards Sapien Implanted in 21-mm Medtronic Mosaic Bioprosthesis**

(A) Fluoroscopic identification of the Medtronic Mosaic bioprosthesis. (B) Positioning of the Edwards Sapien valve relative to the radiopaque eyelets of the Medtronic Mosaic valve located near the apices of the stent posts. The 23-mm Edwards Sapien valve has a height of approximately 14 mm. The 21-mm Medtronic Mosaic valve has a height of approximately 15 mm. In this case, the upper edge of the Edwards Sapien valve should be either aligned or 1 to 2 mm below the eyelets of the Medtronic Mosaic valve. (C) Balloon deployment of the Edwards Sapien valve. (D) Final contrast aortography revealed no aortic regurgitation.

ropean Society of Cardiology valvular heart disease guidelines, percutaneous balloon interventions should be contraindicated in the therapy of stenotic left-sided bioprostheses (63,64). In cases of homograft degeneration, the “aortic wall” of the prosthesis is frequently calcified; anecdotally this may increase the risk for root rupture during balloon aortic valvuloplasty.

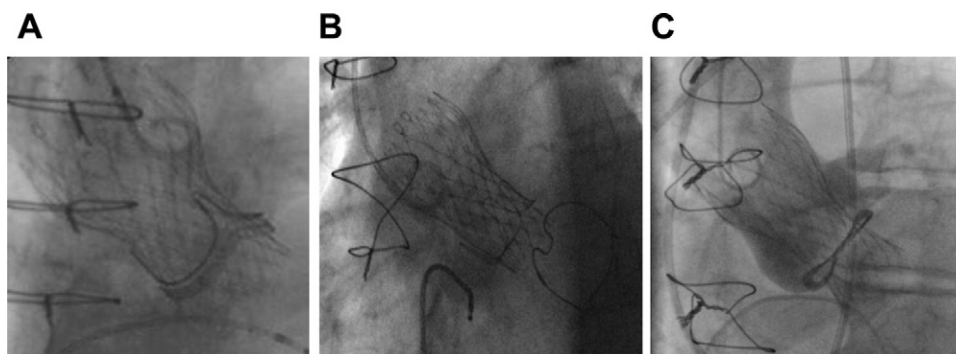
**Positioning and deployment.** There are a number of considerations during the positioning and deployment phases of a TAV-in-SAV procedure. Radiopaque components of stented valves (base ring and/or stent) serve as perfect markers for positioning of transcatheter valves (Figs. 7 and 8). Other possible markers for positioning include the use of repeat aortic angiograms, transesophageal echocardiography, a pig-tail catheter lying in the base of the prosthetic leaflets, and/or identification of calcific spots.

The fluoroscopic viewing angle for valve positioning and deployment should be perpendicular to the base ring of the surgical prosthesis (if visible). Otherwise, contrast

aortography can help select the correct viewing angle. Furthermore, the transcatheter valve should lay coaxial within and lay 3 to 4 mm below the base ring of the surgical prosthesis. Because of its “direct access” route, transapical valve implantation may facilitate coaxial alignment of the transcatheter valve. As opposed to the retrograde approach, the transapical approach may facilitate crossing of the stenotic bioprosthetic valve.

A significant number of patients with degenerated aortic valve bioprostheses have existing aortic regurgitation. In these cases, rapid pacing can be used to reduce cardiac output and stabilize positioning of the transcatheter valve.

During SAV replacement, the stent posts of surgical prostheses are oriented in line with the native commissures and away from the coronary ostia. It is possible, however, that the surgical bioprosthesis is oriented wrongly and the stent posts come to overlies the coronary artery ostia. This



**Figure 8. TAV-in-SAV Implantation Using the Medtronic CoreValve Prosthesis**

Medtronic CoreValve prosthesis successfully implanted within (A) Edwards Perimount, (B) Carpentier-Edwards Porcine Supra-Annular Valve, and (C) Sorin Soprano bioprosthesis.

situation may lead to coronary artery compromise during the TAV-in-SAV deployment (for a case example please refer to the accompanying article in this issue of *JACC: Cardiovascular Interventions* by Piazza et al. (65) describing the German Heart Center Munich experience with TAV-in-SAV).

**Durability issues.** As long as there are no long-term experimental or clinical data, we can only speculate on the potential durability issues associated with TAV-in-SAV implantation. Underexpanded transcatheter valves may be associated with leaflet redundancy and increased leaflet stresses that negatively influence durability. As opposed to the native stenotic aortic valve that is typically associated with asymmetric calcifications and an oval annulus, the rigid base ring of a stented valve may provide the necessary platform to produce a nearly circular transcatheter valve that allows for optimal leaflet geometry and durability.

### Other Indications: Transcatheter Valve Implantation for Failing Surgical Prostheses

There is also interest in transcatheter valves for failing surgical mitral valve bioprosthesis (66), surgical mitral valve repair (i.e., valve-in-a-ring) (67), and surgical pulmonary valve bioprosthesis (44). Transcatheter valve replacement with the Medtronic Melody or Edwards Sapien prosthesis for a failing right ventricle–pulmonary artery homograft is well established. Specific considerations for these applications are beyond the scope of this article.

### Conclusions

With an aging population, improvement in life expectancy, and significant increase in the use of surgical bioprostheses, structural valve deterioration will become more and more prevalent. TAV-in-SAV implantation, because of its minimally invasive character, may prove to be a safer and just as

effective option than redo surgery. Of course, prospective comparisons with large number of patients and long-term follow-up are required to confirm these potential advantages.

TAV-in-SAV implantation may even “disrupt” conventional surgical practice patterns. Eventually, we may observe a larger number of younger patients (age <60 years) being referred for surgical bioprosthetic valve replacement given the option of a TAV-in-SAV implantation in case of future structural valve dysfunction.

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**Key Words:** aortic regurgitation ■ aortic stenosis ■ bioprosthetic valve failure ■ surgical bioprosthetic valve ■ TAV-in-SAV implantation ■ TAVI ■ TAVR ■ transcatheter aortic valve ■ transcatheter aortic valve implantation ■ transcatheter aortic valve in surgical aortic valve implantation ■ transcatheter aortic valve replacement.

## APPENDIX

For the dimensions of some commonly inserted stented and stentless devices, please see the online version of this article.